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ABSTRACT

An appropriate approach to the issue of argumentation for science learning would follow a socio-constructivist perspective that takes into account the role of language and social context in the process of learning. Moreover, although Toulmin's model offers interesting insights to the study of argumentation, particularly in identifying major components of an argument, it relies on assumptions that are limiting in the context of science learning. Within Toulmin's perspective, the individual who constructs the argument would not necessarily construct new understandings through that process, but rather would engage in argumentation to persuade others of soundness of her/his (already developed) ideas. In contrast, the approach of authors such as Dianne Kuhn considers argument as dialogic thinking, describing it as a much more dynamic process that underlies the way(s) people make sense of the natural world. In other words, when Kuhn talks about argument, she is referring to not only how one presents/communicates his knowledge about the world and responds to criticism, but to the way one thinks and constructs new understandings. This perspective has the potential to shift the focus from confrontational to collaborative argumentation and its processes, which is more coherent with socio-constructivist perspectives. (Contains 49 references.) (MVL)

Learning Science through Argumentation: Prospective Teachers' Experiences in an Innovative Science Course

by

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Learning Science Through Argumentation: Prospective Teachers' Experiences in an Innovative Science Course

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1 The significance of Argumentation in Science Education

Various authors have called attention to the significance of argumentation to science education (e.g., Driver, Newton, & Osborne, 2000). First, learners can experience scientists' practices that would situate knowledge in its original context (Brown, Collins, & Duiguid, 1989) as well as provide opportunities to learn *about* science, not merely science concepts (Driver, Newton, & Osborne, 2000; Osborne, Erduran, Simon, & Monk, 2001). Second, learners understandings and thinking can become more visible (Bell & Linn, 2000), representing a tool for assessment and self-assessment (Sandoval & Reiser, 1997a; Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2001). Third, argumentation can support learners in developing different ways of thinking (Kuhn, 1991, 1992, 1993), and facilitate science learning, taking into consideration the role of language, culture and social interaction in the process of knowledge construction (Pontecorvo, 1987). Finally, through argumentation science learners become producers of scientific knowledge and not merely consumers of this knowledge (Brown, 1998; Candela, 1998). Furthermore, reform documents recognize aspects of argumentation as essential features of classroom inquiry, including "giving priority to evidence in responding to questions", to formulate explanations from evidence and to communicate and justify explanations (National Research Council, 2000).

Despite the strong support for argumentation, both in research in science education, and in educational policies, argumentation practices had been rare in science classrooms (Newton, Driver, & Osborne, 1999). Teachers' lack of pedagogical strategies to support students in engaging in argumentation, as well as the limited resources to assist teachers in doing so have been identified as the major barriers to the inclusion of argumentation in school science (Driver et al., 2000; Zeidler, 1997). It is unrealistic to expect teachers to adopt argumentation as a pedagogic practice to teach science if they do not develop more elaborated understandings of argumentation in the context of science learning themselves. Such development is possible only if teachers engage in "the practice of constructive argumentation" (Zeidler, 1997, p. 485). However, virtually nothing is known about how science teachers (and, in particular, future science teachers) engage in argumentation *as science learners to construct knowledge* about the natural world and the practices of science (Newton et al., 1999; Zembal-Saul et al., 2001). The present study has the potential to shed some light on this issue. It provides new insights into designing experiences for engaging prospective science teachers as learners using argumentation. Moreover, it calls our attention to the complexities of the process of learning science through argumentation, pointing to some aspects that have been overlooked by science educators.

2 Understanding of Argumentation in the Context of the Present Study

The authors believe that an appropriate approach to the issue of argumentation for science learning would follow a socio-constructivist perspective that takes into account the role of language and social context in the process of learning (Pontecorvo, 1987; Vygotsky, 1978). Moreover, we argue that although Toulmin's model offers interesting insights to the study of argumentation, particularly in identifying major components of an argument, it relies on assumptions that are limiting in the context of science learning. Within Toulmin's perspective, the individual who constructs the argument woul not necessarily construct new understandings through that process, but rather would engage in argumentation to persuade others of soundness of her/his (already developed) ideas (Toulmin, Rieke, & Janik, 1979). In contrast, the approach of authors such as Dianne Kunh (1991, 1993) considers argument as dialogic thinking, describing it as a much more dynamic process that underlies the way(s) people make sense of the natural world. In other words, when Kuhn talks about argument, she is referring to not only how one presents/communicates their knowledge about the world and responds to criticism, but to the way one thinks and constructs new understandings. We believe that this perspective has the potential to shift the focus from confrontational to collaborative argumentation and its processes, which is more coherent with socio-constructivist perspectives.

3 Methods

3.1 Context

This study describes research conducted in an innovative multidisciplinary science course for prospective teachers (PTs) offered through the College of Education at a large university in the northeast United States. The course, *Technology Tools for Supporting Scientific Inquiry* (SCIED 410), was a content course composed of three instructional modules, focusing on life science (evolution), physical science (light) and earth science (climate change). In each unit, PTs were confronted with guiding questions, required to assess different types of evidence, and worked in pairs to build evidence-based arguments and present their conclusions to peers. In the evolution module they would respond to the questions 'Why so many finches died in Daphne Island in 1977?, and 'Why some were able to survive?'; in the Light module the question was 'Why do we see what we see?'; and, finally, in the Climate Change module 'Are global temperatures increasing?', 'What is causing changes in global temperatures?', and, 'What would be the consequences of Global Warming?'.

Various technology tools, such as The Galapagos Finches (Evolution module), Progress Portfolio (Light module and Climate Change module), and World Watcher, (Climate Change module) were used to support PTs' scientific inquiry (Edelson, 2001; Loh et al., 1998; Tabak & Reiser, 1997; Tabak, Smith, Sandoval, & Reiser, 1996). Following each module, there were lessons in which PTs reflected on their experiences in the unit, connecting these experiences with key concepts associated with the nature of science. The other major task PTs had in the course was to develop a web-based philosophy of science teaching and learning in which they discussed their understandings of nature of science and scientific inquiry, science learning, and the use of technology in science education.

3.2 Participants

The study addresses the experiences of four prospective teachers. Leila (pseudonym) was a 19 year-old freshman majoring in Spanish Secondary Education. Her experiences with science learning reflected a more traditional way of teaching: memorizing information from textbooks, following directions during labs and attending to lectures at the college level. Although these experiences were perceived as negative, Leila saw scientific knowledge as very valuable. However, still, "*science would bring a bad taste to her mouth*" and she would say she did not "*drink in the same cup*". She explicitly explained that her problem was with "*having to learn science.*"

Conrad (pseudonym) was a 22-year-old college student majoring in secondary science with focus on Chemistry. He was the participant who was more advanced in his program, being in college for two years. What he liked about science and, particularly, mathematics was the structured way of thinking involved in these disciplines. "*Yeah, science has always been my thing and I guess chemistry...*". However, Conrad could hardly recall experiences learning science prior to college, except for a very authoritative Earth Science teacher in high school. Latter, in college, he would have positive experiences taking courses with small classes (5-10 students) and with professors that were role models for him. In these courses, he learned about ideas and principles instead of 'facts', and he had a chance to have open-ended experiences in science learning. Based on these experiences (negative and positive), Conrad defined good science learning by saying that "*Learning should be a discussion not a speech.*"

Caroline (pseudonym) was a 20 year-old freshman majoring in elementary education. She had a series of positive experiences in learning science in the past. These experiences involved being active and creative, sometimes with hands-on activities, sometimes with projects and presentations. They also involved a contact with concrete aspects of life outside school, such as going to a field trip outside school, seeing pictures, bringing animals to the classroom, or role playing to simulate a real life problem situation. However, later in high school she would have only negative experiences, which, like in Leila's case, were related to a more traditional way of teaching (e.g., being lectured, memorizing information, copying and following directions, and learning about abstract topics which were not connected to her everyday life). Although positive experiences were remarkable, after SCIED 410 was over, she would talk about how learning science was not particularly motivating for her: "I am not gonna say that I am not happy that I don't have to take science courses anymore."[1]

Finally, Matt (pseudonym) was a 19 year-old freshman majoring in Social Studies Education. He had little interest in science: *"Science is not something that I really care about, like history. I cannot stomach more than one semester."* This lack of interest was related to the fact that science was about things not people. For Matt, Chemistry was the epiphany of what science is: you mix things, you follow directions, you have to find the right answer, even if you got the wrong results. In science, there is no room for different opinions, and there is always one right answer. Nevertheless, he described a positive experience learning science in which his high-school Biology teacher "*would lecture on something and then I think he usually went back and did some kind of experiment or lab that would prove it.*" Thanks to this teacher, he could still remember a lot about what he learned at that time. In some cases, negative experiences were related to a complete lack of interest on the subject matter (e.g., anatomy). However, interestingly, his Physics class, "*the closest thing to inquiry-based education*" was also described as negative. In this case, the teacher "*left the class in anarchy*" while students would struggle "*trying to get answers any way they could*".

3.3 Research questions

The researchers adopted a naturalistic approach with a case study research design informed by grounded theory and phenomenology theoretical frameworks. The research questions were: 1) How do prospective teachers (PTs) perceive the experience of engaging in the process of situated argument construction as students in a innovative science course?; and 2) What factors account for participants' perceptions of the process of argument construction in SCIED 410?. In the present paper, we addressed this question focusing on how participants' experiences would be related to aspects of the

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[1] In that university, all students majoring in education were required to take 3 science courses. Caroline was relieved she had concluded this requirement.

immediate context as created by instructors, specifically, aspects of the curricula and technology tools that were part of the course.

3.4 Data Sources and Analysis

The sources of data for the study were (1) PTs' electronic artifacts constructed in the course, and (2) interviews with participants conducted after each unit, plus a follow-up interview a semester after the course was concluded (totaling 5-10 hours per participant).

The structure of participants' arguments was analyzed to determine the extent to which PTs explored multiple explanations, provided relevant evidence to support their conclusions, explained how evidence and conclusions were related, recognized limitations in explanations, and used discipline-specific knowledge to construct their arguments. Interviews were analyzed using methods from grounded theory. Open coding and axial coding were generated through comparisons of data to develop concepts that reflect participants' perceptions of the process of argument construction. The analysis was structured around comparisons between individual participants across different modules in the course, as well as across participants, permiting the identification of *changes* over time and *differences* among participants (Charmaz, 2000; Glaser & Strauss, 1967). Initially, through open coding, some categories and their properties were developed (Strauss & Cobin, 1998). Then, through axial coding, the researchers established connections between categories and subcategories (Strauss & Cobin, 1998). In this phase the initial codes were raised to conceptual categories, which were not merely descriptive, but analytic and sensitizing (Charmaz, 1990; Glaser & Strauss, 1967).

4 Results

4.1 Examining Participants' Arguments

Comparing the arguments that the two pairs constructed across the modules, the researcher noted first, that evidence is used to support claims consistently in all the three modules. Second, there was a development in terms of being able to better characterize pieces of evidence, as well as to make explicit assumptions in the justification. That is particularly notable for Caroline and Conrad, because in the first module they appeared to try to avoid making interpretations when describing the evidence. However, some limitations persisted until the end of the course. The analysis of PTs' arguments indicated that, to separate evidence and justification was a continuous challenge, with both pairs frequently including part of the evidence in the justification. Interestingly, in our interpretation, after the first module they did not do the opposite, that is, to include assumptions and connections to the claim in their description of evidence. Moreover, only in the Evolution module PTs addressed the problem considering multiple explanations. Furthermore, also only in this first module participants evaluated their own explanations. In other words, usually the participants did not *think about* their arguments, and they tended not to generate counter arguments or recognize explicitly limitations. Finally, at any point they tried to evaluate explanations considering them in the context of possible (i.e., alternative) explanations.

In our interpretation, the major aspects that distinguished the two pairs were that, on one hand, Caroline and Conrad were able to construct well-structured arguments, following systematic and organized paths, demonstrating a solid subject matter knowledge. They also frequently revised their arguments and reconsidered their ideas, in a way that the final argument was considerably coherent and cohesive. They pursued such a coherence and cohesion even when not required to, like in the Light module, when they constructed a page 'putting together' all their claims. On the other hand, Leila and Matt included in their arguments questions and wonders, they pointed contradictions, they pursued questions, they used their own language, particularly, in the first module. This is even more interesting considering that their arguments, in general, were not as logically structured, had fewer pieces of evidence and contained more contradictions, compared to those of Caroline and Conrad. For the researchers, this indicates that this pair was engaging in the process of argument construction in a more "authentic" manner, that is, they included aspects that were personally relevant for them because they emerged 'naturally' from their investigation. In certain instances, this attitude appears to have worked in their favor. Contrary to the other pair, in the Climate Change module, for example, as Leila and Matt investigated the relationship between population density and

CO_2 emissions, they were able to identify exceptions that would go against the expectation that there would be a direct relationship between these two. Moreover, they implicitly identified possible limitations in their explanations, creating a potential space for further investigation, and, thus, further learning.

As instructors, we considered all these PTs good students and all of them got As in the course. As researchers revisited the same arguments that were evaluated in the present study, some limitations in their knowledge of the subject matter as well as their knowledge about argumentation surfaced. However, both pairs would be characterized as successful in building and using arguments in science learning in that particular context. Considering these findings in the context of the goals of science education reform, one could say that learners came to be relatively proficient in the practices and discourses of science (at least in those that were the focus of the course). In addition, one could argue that since they knew how to do and how to *use* these practices these PTs did learn science, and argumentation was a key aspect in this process. The questions that emerged at that point is: "Would PTs who participated in this study agree with the researcher?" "If we knew more about the process through which they constructed their arguments and the meanings they attributed to these processes would we still describe argumentation in science learning in the same way?" Thus, we came to the realization that there is not enough evidence to say that the process of constructing arguments was important for their learning of science from *learners' perspective.* We need to turn to prospective perceptions of the experience of engaging in argumentation, listening to their voices.

4.2 The Experience of Argument Construction: Prospective Teachers Perceptions

In addressing the question 'How did prospective teachers experience the situated process of argument construction in science education?', I focused on what were PTs' perceptions of the very experience of argument construction that they engaged in. To construct arguments in the context of this particular science course, prospective teachers engaged in a process of using the structure that was given by instructors. "Using" such structure did not imply in embracing the same meanings and processes envisioned by educators. As learners constructed and attributed their own meanings to the structure, they developed their own rationale and actions. Thus, what initially was an abstract and given "argument" gained new life: complex processes started to take place in the *situated* argumentation, processes not necessarily anticipated by those who designed the structure. Situated argument construction for prospective teachers involved two major processes: *argument building as legitimization*, or the use of the argument structure to make one's argument valid and acceptable, and *argument building as means*, or the use of argument in facilitating or inhibiting the process of development of explanations to better understand a problem. In the first case, the focus is on gaining 'authority', in the latter the focus is on gaining 'ability' to construct explanations. These processes were not mutually exclusive, participants experienced them across the course in different modules, and in the same investigation in different situations. Nevertheless, argumentation as legitimization prevailed. It is the most powerful process driving PTs' experiences, and they consistently relied on this type of process to proceed with argument construction.

4.2.1 Argument construction as Legitimization

> *"like one time like one graph we chose to make was like of the beaks versus like living and dead birds and we were like, oh, look at this, you know, because it was all separated. And we just came up with that hypothesis. And* ***so that was like our initial hypothesis. And then it was kind of like we didn't explore any other hypotheses and so we just... we just filled in the information. Like, we went back and made it true. But it actually was true, so it was kind of like... Like it could have been bad if it wasn't true.*** *You know? But it kind of worked out okay."* (my emphasis)

Leila – Post-Evolution Module Interview

Leila's account of how they constructed their argument in the Evolution module represents an extreme illustration of what we interpreted as legitimizing arguments to be: to make something true. Although legitimizing is rarely expressed in this extreme form, the issues underlying this type of experience were present throughout the course. How can I make my explanations acceptable? What should be key characteristics in my argument for people to see it as a valid idea? What makes explanations worth? Note that to "make it true" (or to make it acceptable) does not always imply that "it is true" (or that it is an explanation that helps me to learn about the natural world). These are seen as two distinct processes, and notably, legitimizing the argument came first. The major concern, at that stage, was to *make* the explanation acceptable, not exactly to see if that explanation had the potential to account for the various aspects of the problem posed. Consequently, in this context, the problem acquires a different function. The learner is not trying to understand the problem and to solve the problem; he/she is basically looking for an *acceptable solution*.

Legitimization was the most predominant process throughout the course, with all participants experiencing it frequently. However, in my interpretation, this experience was particularly recurrent in the Light module, constituting the core of argument construction in this case.

Considering legitimization's specific role, what do I do to my explanation so it is appropriate? Three attributes were identified as being important for PTs in SCIED 410: argument is concrete, argument conveys a clear message, and argument is articulated in an appropriate manner. Notably, these aspects of legitimization are recognized by PTs as related to a *context for legitimization*. In the present paper, I will focus on two of these attributes: concreteness and conveying a clear message.

Concreteness

This attribute represents the notion that for participants, to have something tangible and concrete was essential to make one's argument valid. In fact, in many instances it is expressed that you cannot even say anything if you don't have tangible evidence to say it.

As one relied in this 'concrete information' or 'concrete reasoning', the best she/he could get was to have *physical evidence* to show that her/his ideas were valid. In other words, the 'highest status' of concreteness was to have the 'material'/ 'physical' to support your explanation. There is a clear difference between having and not having this type of evidence: I see it or I don't see it. These differences between seeing and not seeing, acquired deeper meanings in the context of science argumentation and learning in SCIED 410: physical meant certitude whereas not physical meant questionable and uncertain.

M: I thought J's [Light module instructor] were black and white. Like there was no other way you could see it. It was like a fact. So that's the difference.

I: The light. Did you feel more confident when you made your claim?

M: I felt more confident in the properties I was discussing. Yeah, and more confident in the claims I think because... umm... like light is reflected, you know there's no other way you can interpret that. With this, I think it's just because like even there's so many experiments that like it could, that like there could be like an outside variable affecting it and there's just no conclusive way to put it. Like you can make a hard case against it but you're not gonna prove it one hundred percent. Where with the light, like light is always going to reflect at that angle, it's like it's a property, it's a fact.

Matt – post Climate Change module interview

In my perception, as PTs moved from constructing explanations based on indirect evidence (e.g., changes in patterns of traits frequency in a population in the Evolution module) to constructing explanations based on experimental evidence, they felt much more confident about the validity of their argument. If you "see" something happening, there is little (or nothing) to be said, to be explained and to be discussed. It is as if 'reality' had materialized in front of your eyes.

Conveying a clear message

In the quote presented above, Matt talked about how having something concrete made their argument stronger. In both cases, underlying the notion of having something concrete was the idea that the concrete make things "clear" and unambiguous. 'What else could one see here?' This power deriving from concreteness, but that can also originate through other processes, is represented in the concept of "clear message". It rests on the notion that in a "good argument" there was no place for uncertainties and ambiguities; what should be presented was a clear message showing how a particular explanation was *the* right one.

Nevertheless, predominantly, there was, in our interpretation, an active process of suppressing conflict and ambiguity from the argument to make it reflect an apparent agreement. Sometimes, eliminating conflict demanded a lot of effort, like when Conrad decided to completely ignore some initial ideas that he had about light's behavior.

I learned that it travels in waves and that like the speed of light is the wave length times the frequency is basically just what I've dealt with in like two semesters now of physics. And now I came here and saw that it travels in straight lines. So I don't know what to believe.

Conrad – post Light module interview

Despite this consciousness of deep conflict, in Conrad's argument no reference to this ambiguity and his struggle to deal with it was included in the argument and he does not want to discuss it in class:

C: I didn't say anything in the class itself because ***I thought that would get everybody off track and mess everybody up.*** *Whereas, it wasn't that important to me to like take the class in a different direction than it was going. I don't know. (...) I don't know that I ignored it. I more.*

I: You kind of decided not to bring it up.

C: Yeah. ***I avoided the conflict pretty much. Like I didn't want to open that can.***

Conrad – post Light module Interview (my emphasis)

Consequently, all the conflict he experienced at the beginning of the unit (and that lasted until its very end) was not made part of his argument. In other words, exploring or even describing conflict did not became part of his experience in constructing arguments.

4.2.2 Argumentation as means to understanding

What we did is, when I said we went through and checked the heavier and longer wings and longer beaks and longer legs, or the trait that made, we made graphs for *all of them and we tried to. Before we even explored any one of the hypotheses, we decided that we were gonna check them all out before we went back and picked one to focus on... or maybe more than one. But as it turned out, the beak length was the one that jumped out at us and we were running out of time, so we just kind of focused on that. (...) It was probably like four or five graphs in a row where we just did trait after trait to try and see which one was the trend.*

Conrad – Interview Post-Evolution Module

The notion underlying the concept of argumentation as means to understanding is that participants not always focused on making an argument acceptable, in some instances, their major concern was interpreted as being to find an explanation that would better account for the problem that was posed, like in Conrad's comments presented above. In this case, participants described their approach to the problem in a very different manner in comparison to Leila's description of "making it true" (p. 9-10). They explored multiple possibilities, and, based on evidence, they made choices not only about what was a 'good' explanation, but also on *how* to proceed in their investigation (e.g., focus on an specific explanation). In this context, argument building is seen as *means to understanding*, instead of as legitimization. There is a genuine concern with understanding the problem, although, as we will see, this can have a very specific meaning in the context of SCIED 410. Two major sub-categories were created to represent the experience of argument construction as *means to understanding*. It can involve, on one hand, seeking *guidance* in the structure or, on the other hand, sensing such structure as an *impediment* or constraint. Both categories are related to asking the questions: 'Where do I go from here?' 'What should I do now?' To have instructors' structure as guidance means that using such structure facilitates the process of explanation(s) construction. To face *impediment* is to envision other ways to go about solving a problem, but feeling trapped by the structure. Moreover, one could think of the use of argument as guidance in two ways: it can guide participants *actions* to better pursue the problem or it can guide them in a very specific set of steps *as formula*. In the first case, argument guides PTs in providing *ways* to approach the problem at hand.

He/she is not using the structure as *the* path to be to get to a 'specific answer' to the problem (guidance as formula).

Guidance for Action

Guidance for action occurred in various forms. For instance, having a question as part of the argument helped PTs to focus, or making claims more concise supported them in identifying key ideas to be pursued. In this paper, I illustrate the category guidance for action through an example that, in my view, has a clear parallel with the notion of 'thinking as argument': the use of evidence to construct theories (or the coordination of evidence and theory) (Kuhn, 1991). In some cases, finding additional evidence was seen as the only way to continue constructing explanations. In these cases, the question is clear, but having elements to respond to the question become decisive. This type of experience can be illustrated through Conrad and Caroline's experiences in the Evolution module:

> *And then we went to check the field notes and the longer legs and longer wings. I forget which one, but one of them we thought might have been a factor. I think it was the wings. But then we couldn't find any evidence in the field notes to show any advantage that that would have... And the field notes all pointed to longer beaks being able to eat the tribulus plant.*
>
> Conrad – post Evolution module interview

> *We did check out a little bit of the evading and the mating to see if we saw anything else maybe that had to do with leg length or wing length. And we really didn't see much. It was actually difficult to find stuff like that related to leg length or wing length. But it was pretty easy to find stuff with beak length because, you know, eating the seeds and stuff like that, there was a lot of information with that, especially with the tribulus plant which was really helpful because that was the most prevalent plant.*
>
> Caroline – post Evolution module interview

Working together, Conrad and Caroline were struggling to use leg length and wing length to explain finches' survival. They did not know how these traits could lead to survival, thus, they looked for further evidence that could guide them in their exploration of such options. That is, they believed that by looking at more evidence they would be able to construct an explanatory framework for how bigger legs, for example, would increase chances of survival and/or reproduction. They ended up abandoning such explanations, and focusing on (and finally accepting) only one of the multiple explanations that they initially constructed.

All participants experienced guidance for action in argument construction, but for Conrad and Caroline that was a predominant part of the process. Furthermore, in all the modules guidance for action occurred. However, in the Evolution module, guidance for action not only occurred more frequently, but also acquired a variety of forms. Notably, this is the only module in which evidence played an important role in guiding participants thinking. In the Light module, guidance rarely occurred. In fact, guidance for action partially failed in this module, since the question would be confusing instead of helpful for students in this context. However, we should note that making claims concise supported students in articulating their ideas. Finally, in the Climate Change Module, guidance for action did occur, but basically in respect to using questions to focus.

Guidance as formula

Guidance as formula means having clues that will lead you to a particular "right" solution to the problem. In this case, the structure would tell learners about what components the final 'answer' should have, and based on these components one could 'deduce' the answer. In our interpretation, all participants talked about this type of experience, except Conrad. However, for Matt and Leila, guidance as formula was particularly important in the process of argument construction, especially in the Light Module. Matt's comments illustrates this notion of the structure that worked almost like a template to be filled in, or a check list to be completed:

I: So, Matt, one more thing that you mentioned in here. So the difference in here is that, again, it's that we are breaking into three parts. Do you think this is important, helped you somehow?

*M: **Well, it's helpful that you're gonna ensure that you're not going to forget anything.** If you wanted to put this into a paper then, it'd be real easy because you have all three parts that you need right there and it's just a matter of, you know, tying it all together with your...you know.*

Matt – post Light module interview (my emphasis)

By filling in the template, you make sure you are heading in direction to accomplishing the task and getting to an appropriate solution to the problem. Through the analogy of a mathematical formula used by Leila[2] and her comparisons between structured and open-ended tasks, we could further elaborate this concept, in terms of the processes underlying it.

L: (...) When you give me a formula, I will learn the formula and I will do the formula. And like you brought up how, you know, velocity...if you would give me the equation for finding out the pull of gravity on an object, I could do it. And if you give me like the different variables and I solve it very systematically, that's good. Whereas, when I have. I guess when I have to. Wait. Is that abstract when I have to think abstractly? Like that's like it's mathematical and then or when I have to do something that doesn't have a set pattern to follow, it's more frustrating to me then and so I try not to think like that. I try to steer away from that.

I: You mean if I don't give you the formula and just show you some set of behaviors and you have to build a formula?

L: No, like I would rather do math than explain the natural selection. You know? So I would rather fill out progress portfolio pages for reflection rather than have you guys say, you do this and fill it out the way you would like. You know, because like I always feel like I'm doing it wrong or I'm not doing it right. Like there's a lot of lack of confidence. And even like as a student, even when like if I'm not confident in something and even if I'm doing it right, like I don't think that I am. You know

2 In fact, I did introduce such type of contrast, as she had difficult to articulate how she 'normally' thinks. I compared mathematics and biology, talking about how I would feel in these different contexts of thinking, then she came with this interpretation of what would be for her to think mathematically and its meanings.

what I mean? Like but if I was doing something and like it's structured and it's like just the simple structuredness gives me a sense of like confidence in what I'm doing. So that's why I think I liked the light. Going back to.that's why I think I enjoyed the Light module more because it was more like you're doing this because, you're doing this because. You know, giving me like a reason or explaining why we're conducting these experiments.

Leila – post Light module interview

Notably, Leila's experiences tell us about the deep impact that *guidance as formula* has in the process of argument construction: some people can barely function without such a guidance. To leave it "open-ended" meant to give room for mistakes.

Argument Construction as Impediment

Interestingly, in spite of the impact that guidance had in argument construction and the way it was perceived as extremely important, argument construction was also experienced as limiting. The structure not always was facilitating the development of explanations, specifically for Leila and Matt. As defined earlier, to face *impediment* was to envision other ways to go about solving a problem, but feeling trapped by the structure. Such an experience with argument construction involved a sense of being turned helpless, instead of being helped by the structure.

L: Well, like I feel like this semester, we dealt a lot with like an inductive method of inquiry. You know. And like sometimes the deductive way is better. Like for certain topics. You know, like it's just. And it's all personal preference, I guess. Like the way you learn. I guess... maybe I'm more of a deductive. But like I can do both. It's just sometimes it got very annoying sticking to the same pattern because it just got very monotonous. Especially when you have a long class because you're just like doing it. You know... But it was... I can definitely see how it was helpful like to use [as] teachers like to keep order in the class. Like I can definitely see how that was helpful, but...I have mixed feelings on the whole thing. I do.

Leila – post Global Climate Change module interview

The notion that this process "got very monotonous" is an important aspect of argument construction as impediment, because it implies in a repetitive process that one has to follow. Thus, 'the lack of choice' in relation to ways to construct explanations appears as associated with the notion of constancy and repetitiveness. Again, by just repeating a procedure, new insights on the problem were not generated:

M: Okay. It just seemed like it was the same thing over again and I didn't really... ***I didn't make any further connections or further understandings from doing the argument part of the portfolio in answering the question.*** *It was just like it was copy and paste it seemed. Umm... If I got further understanding from it or was able to make connections better?, I would say it was good to use it, but I really didn't.*

Matt – post Light module interview (my emphasis)

Moreover, the process of argument construction was perceived as the science way of thinking but it had little connection with participants' own ways of thinking, as illustrated in the following quote from Leila:

L: I don't think I'd ever.... I can't... like... I have a hard time. I guess it's just maybe harder for me because I'm not really going into the science teaching field. Because, you know, that's what basically this class is centered around. You know... A hundred percent. But umm... I don't... like... I see it as we're making these arguments for the class and we're organizing it in the scientific way because this is a science class and that's what science people do. But for me, I'm not in the science... like I don't want to go into the sciences and I'm not... like that's not a focus in my life. So I cant ever see myself like structure. You know...

Leila – Post Light module interview

In sum, to construct arguments was experienced sometimes as a sterile process, a mechanical repetition of procedures that resulted in no meaningful outcome. Notably, the process of argument construction has been described by participants much as a process of following paths[3] that are well-established (legitimization) and paths that are pointed (guidance). However, this situated argument construction does not include transgressing

[3] (Bauchspies, in press), talks about well-travelled paths and fences to characterize mathematical education.

paths or constructing new paths. As educator and as researcher we cannot ignore such an absence.

4.3 Argument Construction as Legitimization and Argumentation as Means to Understanding: Shifting Meanings

When one thinks about the two categories that we used to characterize processes occurring in the context of situated argument construction (i.e., argument construction as legitimization and argument construction as means to understanding) he/she should be aware that I intended to represent those categories as distinct, but still closely related. As I examined the participants' interviews' excerpts, such a relationship could be identified in three manners. First, both categories could occur in the same investigation at different times.

> *Well, I guess that more relates to just this program that we had to first generate all the graphs and then from those we formed a hypothesis. And then we went through and tried to test it. By testing it, we just checked out the graphs of all the different options and saw which one was the most prevalent. And then, at the end we had to do the presentation and we have to hand in the final journal and that's gonna be our conclusion. So that you can't just... I guess it's showed me that you cant just say something without backing it up. We actually had to gather the data, say something, and then back it up and explain why we thought so. But that was a good thing... a good way of showing what scientists do.*
>
> Conrad – post Evolution module interview

In Conrad's story, I identified two distinct phases. First, when they were exploring the problem they used the structure more to guide their actions (e.g., generate hypothesis, examine evidence, test hypotheses). Then, they would think about how to present their argument and their journal, focusing on legitimization of their explanations (e.g., "back it up and explain why we thought so").

In our interpretation, it is in the Evolution module that these shifts are clearer in the experience of both pairs. Conrad and Caroline, as described above, started the module exploring multiple explanations systematically. They were engaging in (or using the structure for) guidance for action mainly. They found an explanation that was more promising and they further explored this explanation. In our interpretation, at this stage, they were still engaging in the process of argument construction as guidance, because they were aware of the existence of other possibilities and their limitations and/or strengths. In other words, they were still searching for understanding. It is only at the very end of the module, when they were asked to evaluate and then present their argument, that they shifted to justification. In this situation, for instance, they decided to 'discard' (i.e., considering) explanations that could not be fully explored. On one hand, they would recognize that there was a difference and the data was inconclusive, but, on the other hand, they would simply consider the same explanations as proven wrong. The other pair engages in legitimization earlier in the module. At the very beginning, they were trying to address the problem, but they struggled to find guidance in the context of the Evolution module. They would try different approaches to the problem in a random way, being confused and lost. Then, somehow they found an answer[4]. This changes their behavior: now they know where to go. They adopt a systematic way to approach data centered in legitimization, that is, to make this answer acceptable to other people, in particular, to the instructors. In sum, in the evolution module, shifts from legitimization to guidance occurred for both pairs, involving a movement from searching an answer to having an answer to work with and needing to present or convince someone of the value of this answer.

Moreover, a process of shift from guidance to legitimization or vice-versa also happened as the course progressed and PTs participated in different modules.

L: It's hard for me to think about light in terms of what scientists do because... like I'm probably taking this in the wrong direction, but light has been discovered. You know, like I felt like we were just learning about light, we weren't like investigating light. You know what I mean?

[4] Leila's and Mike's accounts on how they got to the idea that differences in beaks were responsible for the survival of the finches were considerably contradictory. Sometimes they said they found it by constructing graphs, sometimes they said someone told them, sometimes they just said 'we knew it'.

I: So, there's something that people know and.

L: Yeah. Like I see science as more of like investigating, you know, hypothesizing. And with light, it was like, you know, I think we were just learning like a lesson. Like light... like someone already like found out the four properties of light and like we were just being taught that, like we weren't... maybe I missed the point of the whole module, but I didn't see us as investigating light, more as just developing an understanding for light. (...) So I guess I would have to say that the finch module is more like what scientists do. Whereas, like the light was just, you know, presenting information and going from there. Like we didn't... we really didn't have to investigate on our own all that much. Whereas, I think that's what a scientists would do.

Leila – Post-Light module interview

Leila experienced the Light module as learning an answer that was already established, whereas the Evolution module involved responding to a problem that was still open by adopting scientists' practices. We should remember that to know the answer was an essential aspect of the process of legitimization, indeed, its starting point.

Finally, shifts from legitimization to guidance (or vice-versa) could also occur as participants moved from the context of the classroom to the context of research. Conrad represented a particular interesting case because he apparently had very contradictory behaviors in class, when engaging in legitimization, and outside class during interviews. For instance, he, like all the participants, held the notion that, to be valid, an argument should convey a clear message. Accordingly, *in class*, Conrad intentionally ignored a conceptual conflict that he held (*I didn't want to open that can*) (see p. 12). That is, he intentionally and consciously aligned with the 'clear message criteria'. Later, during the interviews, he would be willing to discuss this issue (or open the can).[5] In other words, as he moved from one context to another, legitimization was not important anymore, or at least did not have the same power and/or significance.

[5] In fact, we scheduled a meeting with the instructor to further discuss the issue.

5 Discussion

5.1 Participants' Experiences in Argument Construction and Science as Argumentation

Considering the fundamental role that instructors played in defining the context for occurrence of the process of argument construction, I believe it is essential that we explicitly identify some of the relationships between the context of instruction (or the tasks PTs were involved in) and the occurrence of argument construction as legitimization and as means to understanding. This acquires even greater importance in light of our goal to promote 'science as argumentation' in science classrooms. It is important that we identify conditions that promoted experiences that supported such a goal. In the present discussion, I will first focus on argument construction as legitimization and as guidance because these were experiences that resulted in some kind of action from participants, instead of limiting participants' ability to act (i.e., when argument construction was experienced as impediment).

Various authors have argued that one of the major significances of the use of argumentation in science teaching is that science students have an opportunity to engage in scientific practices. In this context, the 'content of science' is not anymore seen as solely scientific concepts but also practices and ways of knowing through which these knowledge is generated (Brickhouse, Dagher, Shipman, & Letts IV, 2000; Driver, Leach, Millar, & Scott, 1996; Driver et al., 2000; Helms & Carlone, 1999; Lederman, 1992; Matthews, 1998; Turner & Sullenger, 1999). Argument construction as legitimization was the most prevalent process in participants' experiences of engaging in situated argumentation. Despite its limitations, legitimization focuses on *norms* for determining what is acceptable knowledge, an important aspect of the nature of science. In SCIED 410, PTs learned about norms and were able to construct arguments following these norms, and being conscious of their existence and their value. More importantly, they articulated their own understandings about these norms. Thus, in the context of a science course, legitimization has the potential to support *learning about science* in aspects such as what counts as evidence and how you justify an explanation.

However, if we want to promote 'thinking as argument' in science education, students/learners need to engage in this kind of thinking in a way that they can experience its power for understanding the natural world (Kuhn, 1993). In other words, we need to go beyond legitimization, and create conditions for learners to experience *guidance for action* more frequently, using argumentation as a way to learn about the natural world. Through such a shift in emphasis, we believe that learners can develop more robust understandings of legitimization than those observed in the present study.

5.2 Mapping concepts into the context of the tasks: Legitimization versus Guidance and the Immediate Instructional Context

In our analysis, legitimization was perceived as prevalent particularly in the Light module, whereas guidance for action occurred more frequently and in various forms in the Evolution Module. Notably, in the latter, guidance as formula was not taking place – in some cases, despite the effort of some participants to engage in this type of experience. In this section, I will first characterize these two modules, and, then, I will discuss how these differences could influence PTs' experiences with argument construction.

The curriculum for the Evolution module was designed having in mind the goal of promoting a climate of inquiry in the classrooms (Reiser, Tabak, & Sandoval, 2001; Tabak, 1999). Scientific inquiry is described as having students not only developing understandings of scientific concepts but also engaging in scientific practices (e.g., conducting investigations, constructing explanations, using the discourse of science), as well as developing understanding these practices (for instance, by discussing and reflecting about processes through which one constructs scientific explanations) (Tabak, 1999). Importantly, the design of the curricula was oriented by the theoretical perspective of situated learning, in particular by the work of Brown et al. (1989). Accordingly, learning is seen as a process of enculturation into experts' culture (i.e., in this case, scientists' culture). Thus, the focus of both the *Struggle for Survival* curriculum and *The Galapagos Finches* software was on supporting learners in this process of enculturation, so students could become producers of scientific understandings by following scientists' methods. In the context of this curriculum, scientific practices are understood as not only general domain concepts and strategies (e.g., supporting explanations with evidence) but also as discipline-specific concepts and strategies (e.g., using the notion of a relationship between form and function to construct explanations) (Tabak, 1999; Tabak et al., 1996). With this theoretical framework in mind, the designers purposefully chose a probabilistic phenomenon to be investigated through observational approach instead of an experimental one, demanding the use of comparisons. Moreover, learners were expected to use theories to explain specific situations, engaging in a process of theory articulation (Tabak, 1999).

How these principles were reflected in the activities and tasks learners engaged? In this curriculum, the problem that is posed to learners and the data they use to solve the problem derived from an investigation on ground finches conducted by the couple of biologists Rosalyn and Peter Grant in the Galapagos Islands. During the wet season of the year 1976, many birds died in Daphne Island. Learners are asked to explain why so many birds died in that period, and why some were able to survive. Learners are expected to explore multiple explanations for each of the questions and to use a data-rich environment to develop and explore these explanations. The technological component of the unit, *The Galapagos Finches* software, is part of a project called, *Biology Guided Inquiry Learning Environment* (BguiLE). The software is constituted of a series of components involving collection of different types of data (graphs, field notes with behavioral observations of birds, environment characteristics), data recording, and an electronic journal for explanation building (Reiser et al., 2001; Sandoval & Reiser, 1997a, 1997b). This environment is designed to support the adoption of general and discipline specific strategies to construct and examine multiple explanations to the problem posed. In sum, curriculum and technology tools complement and support each other in promoting the goals of the unit.

The design of the Light module, on the other hand, was oriented by a conceptual change theory framework. More specifically, it focused on raising the *status* of scientifically accepted concepts (i.e., light travels in straight line, light refracts, light can be absorbed and reflected). Accordingly, the goal was to promote dissatisfaction with alternative explanations that PTs' initially held, making scientific ideas intelligible, plausible and fruitful. Approaches to teaching within a conceptual change framework can vary considerably (Hewson, Beeth, & Thorley, 1998). For instance, conceptual change was taken into consideration also in the design of the Evolution module curriculum (Tabak, 1999). However, in the Light module, conceptual change was approached much more as an individual or psychological process than as socially constructed process (Kelly & Green, 1998). Initially, we, as instructors, were not as aware of this as we should. It was our belief that having argumentation as part of the module would promote negotiation of meanings. Nevertheless, the module was in fact designed expecting that by following a certain path, which was determined by the instructor, PTs would discard these alternative explanations and adopt the scientific accepted explanation. To respond to the problem of 'Why do we see what we see?', participants engaged in a series of experiments that were designed by the instructor. The experiments were grouped depending on the concepts they addressed (e.g., light travels in straight line), and were followed by a whole class discussion. After that, participants were asked to construct an explanation relating all the experiments. Notably, the path to the scientific accepted explanation was clearly defined with virtually no possibilities for 'transgression': PTs were given only pieces of evidence that could clearly illustrate this explanation, they followed a sequence that would lead them to address only certain aspects of the problem, and they were not given any alternative explanations to explore. Moreover, all the pieces of evidence were experimental evidence.

Interestingly, Progress Portfolio – the technology tool used for argument construction in the Light module – was designed within a theoretical framework similar to the one that informed the development of *The Galapagos Finches* software (Edelson, 2001). However, it is a more flexible tool that has content-neutral structures to support investigations involving data-rich technology tools (Loh et al., 1998). Thus, Progress Portfolio could be adapted to different contexts to promote reflective inquiry (Edelson, 2001; Loh et al., 1998). In the Light module, we used this technology tool mainly for supporting the development of "reflective reasoning and argumentation skills involving coordination of questions, beliefs, and observations" (Loh et al., 1998, p. 2). However, our results indicate that the context in which Progress Portfolio was adopted limited the potential of the tool for that kind of support. This would be expected considering that technology tools are just part of a whole complex context that would promote 'science as argumentation' - with the curriculum having a particular important role (Reiser et al., 2001). In other words, in this case, the curriculum was hindering some of the capabilities offered by Progress Portfolio.

The descriptions presented above illustrate how, in SCIED 410, we had very different modules informed by different theoretical frameworks, and in which technology tools were used in different ways. The Light module had some of the key elements of legitimization, whereas the Evolution module had more room to promote argument construction as guidance for action. First, the Light module conveyed a single clear message, by using unambiguous evidence and not providing room for multiple views (or conflicts). In contrast, in the evolution module, PTs encountered a data-rich environment in which they had to develop multiple explanations. Second, the Light was the 'most concrete' module, based on experimentation that would always provide physical evidence to support the scientific ideas built in class. In the Evolution module, on the other hand, PTs would deal with observational data, using discipline specific concepts and strategies to build explanations. This has the potential to support learners in understanding that science is not always 'black and white', that scientific knowledge is more problematic, and that theories are the lenses we use to make sense of the complexity of nature. In our view, without being conscious of that, we created a module that would provide our students a good example of what is to teach as legitimization (i.e., the Light module). Naturally, this would have great impact on PT's experiences in constructing arguments.

These differences were highly determined by the theoretical orientation informing the modules. One important aspect of this orientation was that, in the Light module, the approach to conceptual change was very restrict, focusing on the status of specific concepts, which was expected to change dramatically ('black and white'). In this case, there was little concern with situating these concepts in a landscape of other concepts, practices in the field, and aspects of learners' orientation to the domain knowledge (Alexander, 1998). This assumption of dramatic change and the decontextualization of knowledge would represent barriers to engage in experiences of 'science as argumentation'. First, this type of dramatic transformations rarely occurs through argumentation (Leitão, 2000). Second, engaging in argumentation involves developing understandings of criteria to evaluate explanation, and this criteria is highly determined by the context in which argumentation takes place (Zeidler, 1997).

Another aspect of the theoretical orientation that needs to be considered is the perspectives underlying the approaches to conceptual change present in each of the modules (curricula in particular). A socio-constructivist approach to conceptual change involves not only considering the status of a concept and/or the conceptual ecology of the scientific field, but also the *conceptual ecology of the classroom* (Kelly & Green, 1998). In the Light module, as we pointed out, the approach to conceptual change was very restrict, whereas in the Evolution module the approach to conceptual change involved consideration of important elements of the conceptual ecology of the classroom (e.g., the 'culture' of the classroom).

Finally, through the comparison of these two modules, it was possible to learn that even topics that were not as directly connected with students' everyday lives (i.e., the evolution of finches in Galapagos Islands), can provide a fertile context for experiences that are coherent with 'thinking as argument'. Science educators had emphasized the importance of participants personal knowledge in argumentation (Jimenez, Rodriguez, & Duschl, 2000; Kuhn, 1991), particularly in conceiving alternative explanations (Brickhouse et al., 2000). The present research suggests that it is possible for students to have experience with 'science as argumentation' even if the topic is not as connected to their everyday lives, as long as a rich context is provided. In this case, in argumentation, the topic per se would not be as determinant in contextualizing knowledge, but the process through which students learn about that topic (Hiebert et al., 1996). Nevertheless, we know little about the implications of such a disconnection with personal knowledge may have in terms of broadening the gap between everyday understandings and scientific understandings (Panofsky, John-Steiner, & Blackwell, 1990). The experience of argumentation as impediment may offer some insights into this aspect.

In sum, the results of the present study suggest that technology-infused curricula informed by a theoretical background which is coherent with the notion of 'science as argumentation' not only can result in more complex and robust scientific arguments but they also can promote more complex and rich *experiences from learners perspective*. Nevertheless, it is worth noting that I am not arguing that we necessarily need to eliminate modules informed by perspectives other than those we are aligned with. In the present research, it was through the comparison of their experiences in different modules that participants were able to make a distinction between the approaches in the two modules (see Leila's comments on p.21). Thus, if we eliminate these different contexts, participants may not be able to make sense of and to articulate the significance of their experiences with argument construction.

5.3 Argument Construction as Impediment and Rigid Structures

It is particularly difficult to make sense of the experience of argument construction as impediment. First, we know little about what participants would see as alternatives to the process of argument construction that they have experienced in SCIED 410. Second, the same participants who most frequently expressed appreciation for the experience of guidance as formula would experience argument construction as impediment. This raises the question, 'How can someone at the same time need a rigid structure and feel oppressed by this structure?'. As we address the issue considering only the immediate instructional context, these challenges are aggravated even more.

However, although we cannot provide a robust explanation of this type of experience based on elements of the immediate instructional context, it is still important to consider how the curricula and the technology tools could be promoting impediment. Prior research indicates that the design of technology tools that included a rigid template could lead to experiences similar to *impediment*. In a study with an initial version of *The Galapagos Finches* software, (Sandoval & Reiser, 1997b) observed that the use of templates reflecting domain concepts sometimes hinder high school students' capacity to articulate their ideas. The authors argued that when learners were uncertain of their ideas, to have to follow the template would make the task of constructing explanations more difficult. In the current version of the software, the templates are available solely as guides, and students do not have to follow this specific structure. In the present study, instructors constructed templates in Progress Portfolio, which required that participants articulated their explanations using claim, evidence and justification. Even when these components were not part of the template (i.e., in the Evolution module), they were part of the rubric used by PTs – who were aware of the criteria used for grading their explanations. These requirements for articulating ideas may have lead participants to experience argument construction as impediment, in a similar way to how high school students struggled to construct explanations using a rigid template. This reflects a constant challenge for instructors, who have to support participants in developing more robust ways of constructing explanations, and, at the same time, they need to avoid imposing barriers for students to communicate their ideas.

5.4 Beyond the immediate contexts: Broader aspects to be considered in understanding the experience of argument construction.

In the previous sections, we discussed how different instructional contexts could facilitate or hinder the occurrence of argument construction as legitimization or as guidance. Nevertheless, in spite of different immediate instructional contexts, still legitimization was the predominant experience across all modules in SCIED 410 (i.e., including the Evolution module). Thus, it is fundamental that we approach this issue by situating immediate instructional contexts in broader contexts. In this discussion, I will briefly address two of these 'contexts': the relationships between conceptions about learning and experiences with argument construction, and the legitimization as a process that is part of schooling. An extensive discussion of these aspects is beyond the scope of this paper. Here, we intend solely to point out how, in our interpretation, there are indications that they are pertinent to understanding the experience of argument construction for science students/learners.

First, prior research has indicated that conceptions and orientations to learning have great influence on learners/students experiences in science classrooms (Hogan, 2000; Tobin, Tippins, & Hook, 1995).[6] Participants in the present study had perspectives on learning that were similar to those reported in the literature (Edmondson & Novak, 1993; Martinez, Saudela, & Huber, 2001; Tobin et al., 1995). These perspectives are further described in detail elsewhere (Munford, 2002), but it is important to emphasize that they parallel key elements of PTs' experiences with argument construction, and that parallels with legitimization prevail.

Second, as noted earlier, I perceived Conrad's experience in the Light Module (p. 11-12) as an example of how individuals could respond differently to the same problem in different contexts. In her work with high school students, Pope (2001) talks about how to survive in school, students behave like chameleons. The same image of chameleons came to our minds when we thought about Conrad: he was adapting to different contexts. Contexts that he was able to distinguish: the interviews where he could learn science, and the classroom where he played the 'school game'.

In fact, this type of perception is not a rare one in the context of schooling, and is not exclusive to students. (Bloome, Puro, & Theodorou, 1989) coined the term "procedural display" to refer to situations in which *teachers* and *students* engage in what

[6] We acknowledge that abilities to engage in science as argumentation are an important factor to be considered. For instance, students with more experience in engaging in scientific inquiry would be more successful in participating in units like the Evolution module (Tabak, 1999). However, this is not the aspect that we are addressing in this paper. Our interest is in students *perceptions* of and perspectives on learning, and how they would affect their learning experiences.

Pope called 'doing school'. This concept was used by (Jimenez et al., 2000) to understand high school students' argumentation in a Biology class. These authors, used discourse analysis to identify instances of "doing science" versus those of "doing school" or "doing the lesson". Conrad's example, offers new insights into what is to "do school". Although he engaged in behaviors like justifying his beliefs, he was not actually engaged in "doing science". Notably, his behavior of "doing science" involved revealing his *uncertainty* about certain phenomenon, the conflicts and confusions that emerged in face of the "scientific problem", and the recognition of limitations in his knowledge that needed to be addressed. This was not part of the process of argument construction that occurred in the course.

6 Conclusion

The present study indicates that elements of curricula and technology tools can have a significant impact in prospective teachers' experiences with argument construction in the context of science learning. Notably, in our interpretation, experiences that parallel 'science as argumentation' occurred more frequently in the context of technology infused curricula designed within a theoretical framework of situated learning. Thus, we propose that, to promote 'science as argumentation' in science school, educators should adopt and develop this type of curricula. Nevertheless, the immediate instructional context cannot account for the variation of PTs' experiences with argument construction. As researchers, we must pay attention to the broader context(s) in which argument construction for science learning takes place. Important elements of this broader context would be learners' perceptions of learning and of schooling, which are influential in the process of meaning making of their experiences. In other words, we should broaden our focus of research on argumentation in school science to include these perceptions.

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